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IMPLEMENTING LEO-TO-GROUND GAUSSIAN MODULATED CONTINUOUS VARIABLE QUANTUM KEY DISTRIBUTION

Abstract

Australia and New Zealand are currently developing an optical communications ground station network to test technologies for optical and quantum communications that will enable faster data transfers and security during information exchange. A goal of the network is to implement Gaussian modulated continuous variable quantum key distribution (GM-CVQKD) between LEO satellites and optical ground stations. This protocol offers quantum cryptography, providing information-theoretic security through quantum mechanics and is compatible with hardware needed for coherent optical communications that satellites are starting to use to combat the crowded spectrum from increased traffic in radio-frequency communications. GM-CVQKD avoids the need for the specialised and complex equipment required by discrete variable QKD to achieve secret key exchange, as it can use cost-effective commercially available off-the-shelf hardware.

We present a study to determine the feasibility of the proposed implementation. In the first step, a model of the quantum signal downlink propagation from a LEO satellite to an optical ground station (OGS) has been created and analysed. This was used to explore adverse effects from varying atmospheric conditions, the Doppler shift due to relative motion between the LEO satellite and OGS, and the presence of an attack/hack from an eavesdropper. The results show that more suitable atmospheric conditions produce a positive secret key rate (SKR) of approximately 0.035 bits/pulse for typical LEO-to-ground links (160 km distance, 90° elevation angle, and 23 km visibility), while adverse conditions such as rain, snow, and fog destroy the quantum link making the protocol inoperational. The effects of Doppler shift are negligible and still permit a positive SKR. The protocol allows the presence of an eavesdropper to be detected so that communications can be terminated.

Initial benchtop tests between a GM-CVQKD transmitter and receiver will be conducted. Horizontal

tests will also be undertaken to show the effects on the detected strength and stability of the quantum signal under real-world atmospheric conditions at long distances. This will demonstrate the capability of GM-CVQKD in a free-space channel to distribute quantum keys securely with the use of modulated coherent light and heterodyne detection with and without the presence of an eavesdropper.

Plans for future relative motion tests are discussed including using substitute LEO satellite platforms such as high-altitude platforms like balloons and spaceplanes as well as suitable OGS systems including acquisition, pointing, and tracking.

The results show GM-CVQKD as a viable protocol for space-based QKD and is a steppingstone towards a global quantum network.